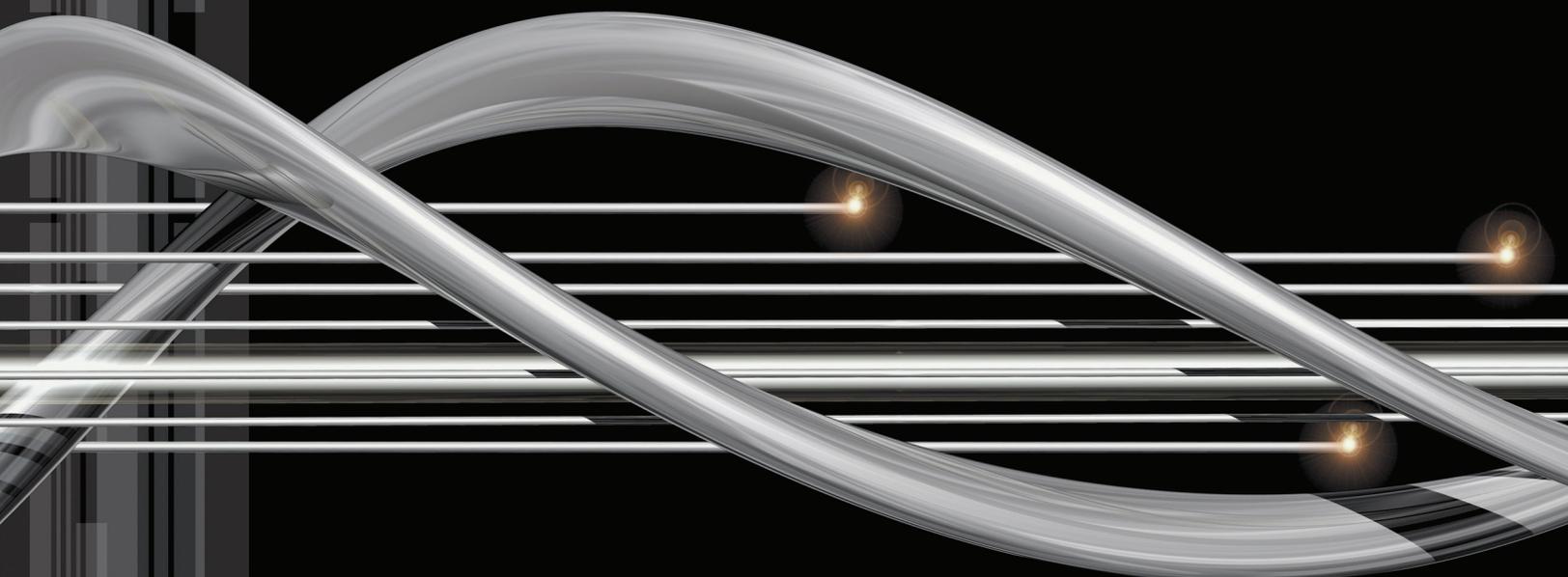


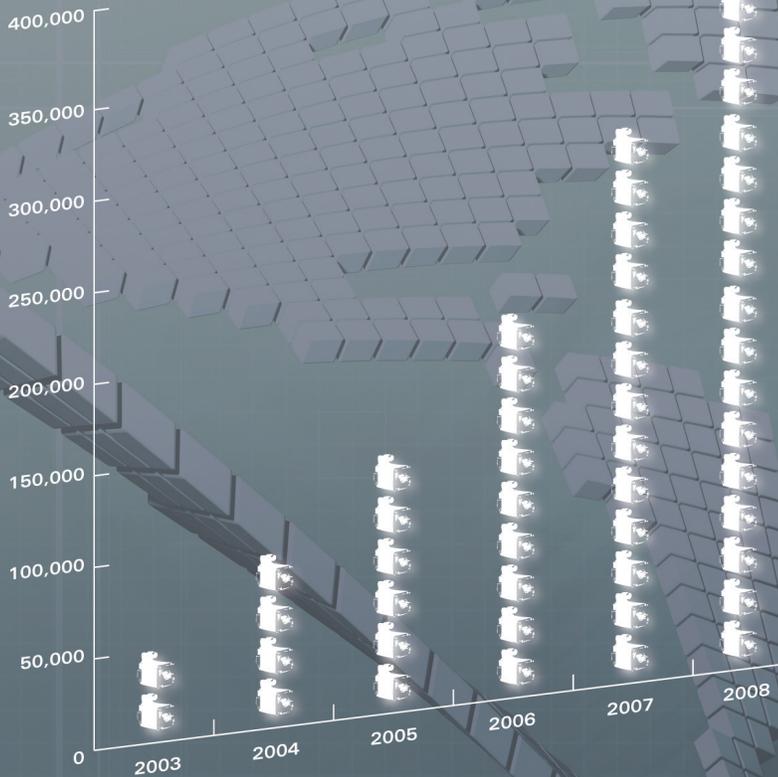
**FAST**

**SAFE**

**PROVEN**



**SynQNet<sup>®</sup>**



SynqNet is the fastest interoperable motion and I/O network.

By the end of 2007 over 350,000 installed SynqNet devices will be driving the World's most demanding motion applications.

Machine builders rely on SynqNet for the highest performance, safety and reliability with the flexibility for unique innovation.

## SynqNet install base through 2008

## SynqNet® – 7 Years of Progressive Development and Proven Success

Launched in 2001, SynqNet is a proven digital network specifically designed to meet the performance, flexibility, and safety requirements of today's demanding machine control applications. Built on the 100BT physical layer but with reduced overhead, SynqNet provides a synchronous real-time connection between the motion controller, servo drives, I/O modules, and custom nodes.

### Highlights

- .: Supports servo update rates up to 48kHz for 4 axes
- .: Support for 32 coordinated axes, 32 nodes, and over 16,000 bits of digital I/O and 1,000 points of analog I/O on a single network
- .: Remote upgrade of any network device / FPGA
- .: Ring, String, or Dual-string topology
- .: Guaranteed multi-vendor interoperability
- .: Customer reference design kits for node development
- .: Remote diagnostics over network
- .: 'Self-Healing' fault tolerance and HotReplace for maximum uptime and safety

### Why SynqNet?

For machine level motion control in highly demanding OEM markets such as semiconductor and electronic assembly, the needs for machine control require something special. SynqNet spawned for two simple reasons. OEMs are always demanding better performance and better pricing. With regards to motion control connectivity, reducing the number of cables and increasing design flexibility are always key. In 2001, there was no solution that combined performance, safety, and diagnostics at a price point to suit OEM requirements. SynqNet emerged as a 'no-compromise' platform to connect motion controllers to drives and I/O devices with a single cable and provide new levels of speed, diagnostics, and safety previously unseen in the marketplace.

### Interest Group

The SynqNet Interest Group has over 180 members. The

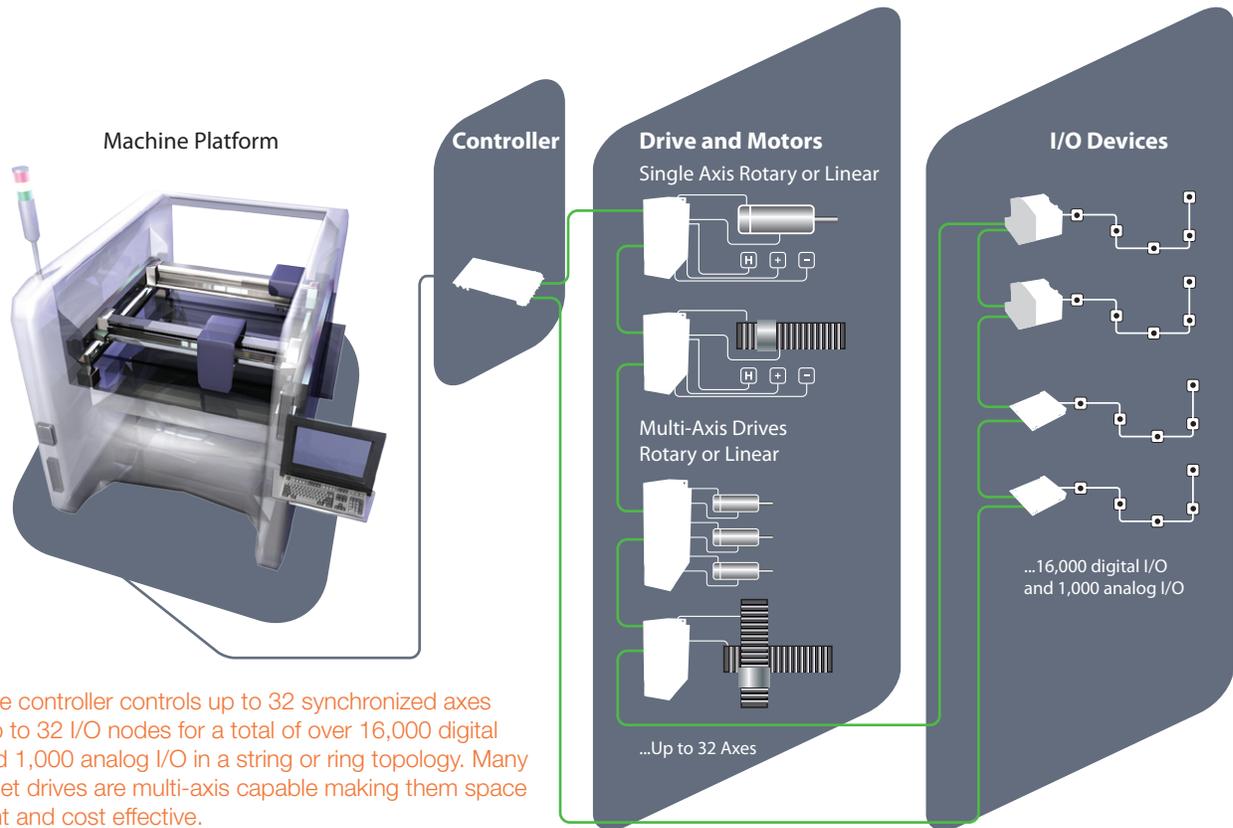
Group includes leading servo manufacturers, I/O device manufacturers, and leading capital equipment manufacturers. Over 500 products are offered globally in a wide range of markets and technology disciplines.

### Have a Technical Question?



Let one of our SynqNet experts answer your question.

[www.synqnet.org](http://www.synqnet.org)



A single controller controls up to 32 synchronized axes and up to 32 I/O nodes for a total of over 16,000 digital I/O and 1,000 analog I/O in a string or ring topology. Many SynqNet drives are multi-axis capable making them space efficient and cost effective.

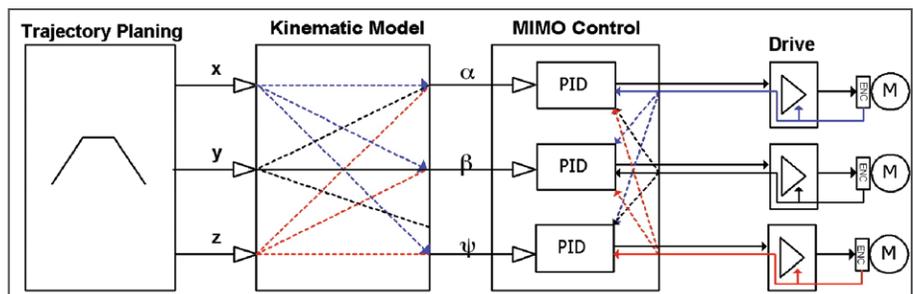
### SynqNet® – Fast across all axes and IO devices

SynqNet uses industry and consumer proven 100 BaseT (IEEE 802.3) CAT 5 cabling with standard connectors and a wide array of custom and other robust industrial connector types.

### Network Latency & Transmission Rate Define Machine Performance

Kinematic models and compensation techniques are not new concepts. They rely upon a central motion processor to perform fast, accurate matrix computations based upon multiple inputs generating multiple outputs. The term MIMO (Multiple In Multiple Out) is often used to describe this generic class of control system and the software control model. Modern control systems take multiple demand inputs and multiple feedback inputs, such as the actual torque and velocity, from each axis to compute new target data for each motor.

For effective high performance control, demand data and feedback data must be transmitted synchronously, with very short cycle times and low latencies. Any transmission delay represents a phase delay in the control system, which limits the achievable gain and the effective response time of a machine.



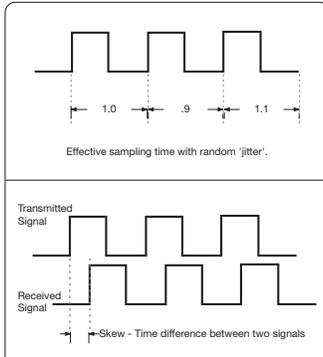
Cycle time includes time to acquire feedback data, time to perform matrix computation, and time to transmit new target data. The key technological elements required to achieving this are a fast synchronous network, and a fast processing engine. MIMO control cannot be performed on distributed control systems that have decentralized processing power, and relatively slow connections between network devices.

It is important that the total servo cycle time is minimized for all types of software control models. The shorter the cycle time, the tighter the control system and the higher the performance of the machine mechanism. For fast point-to-point moves, or accurate path motion, the cycle time becomes a significant factor in machine performance.

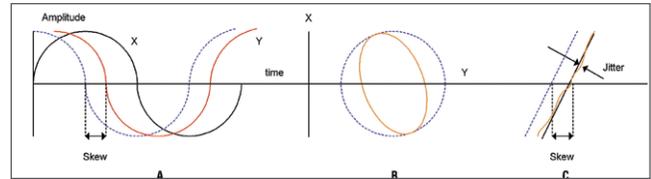
### Why low jitter and skew is important in motion control

Networks consist of multiple transmitters and receivers that send out data on the network at a rate that is determined by its internal clock and digital logic. When independent systems with independent clocks are connected together, as is the case with a network, the natural and random variances in clock frequency can present a challenge. Jitter arises primarily from differences between the local clocks at the master and slave nodes. Electromagnetic interference can also contribute to jitter in a real-world network. This jitter is transmitted directly to the path motion, thus for accurate path motion, it is necessary to have minimal jitter.

Skew is a constant delay of a data transmission between transmitter and receiver, or between network nodes. It's caused by the propagation delay of the cable (approx. 1µs/100m) and delays in internal logic circuitry. For high performance motion control, skew becomes relevant and the network has to be capable of measuring the skew and compensating for it. For a single axis, jitter can result in erratic control behavior such as variation of velocity or oscillatory final position error. For multi-axis systems the results are more severe.



Jitter and Skew



Jitter and Skew effect shown on a 2D circular interpolation and straight line

Skew introduces a constant phase shift between network nodes. Thus coordinated axes do not receive a simultaneous set of command values. For example, assume that you want to carry out a fast circular interpolation with two coordinated axes (e.g. material cutting). In this case, one axis receives a sinusoidal and the second axis a co-sinusoidal command profile. Skew (constant phase shift) will mutate the circle into an ellipse as shown above. Additional jitter would also add some distortion to the shape.

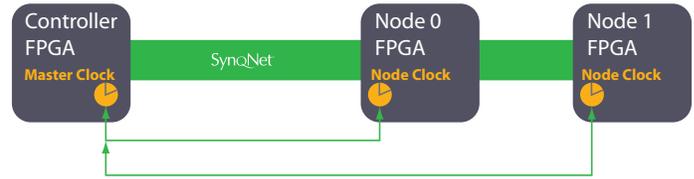
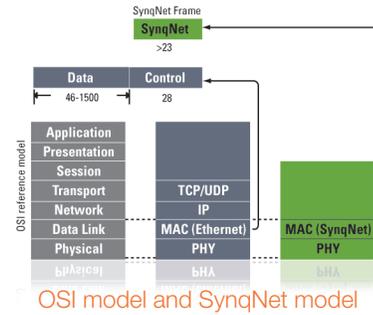
### Network Comparison

The network comparison chart outlines some features of SynqNet and other industrial networks when considering motion control applications. Cycle time performance varies depending on the node structure and control demand. Software related jitter maybe higher for other protocols. All Ethernet based networks have the same EMI characteristics, however SynqNet has automatic bad packet rejection and compensation. SynqNet also has remotely readable error counters with configured thresholds and has ring fault recovery so if a node faults, packets are re-routed. This provides fundamentally superior diagnosis and fault reaction.

	SynqNet®	Ethernet (TCP/IP) (UDP)	EtherCAT®	SERCOS III	Powerlink	Profinet IRT
Motion Control Requirements	Hardware Controller	RTOS + NIC Card	RTOS + NIC Card	Hardware Controller	RTOS + Special NIC or Hardware Controller	Hardware Controller
EMI Immunity	High Transformer Isolation	High Transformer Isolation	High Transformer Isolation	High Transformer Isolation	High Transformer Isolation	High Transformer Isolation
Max. Inter-Node Distance	100m	100m	100m	40m	100m	100m
Min. Cycle Time Latency	<25µs	2-6ms	125..250µs	125..250µs	400µs	1ms
Bandwidth	100 +100 Mbit/s	100 Mbit/s	100 Mbit/s	100 Mbit/s	100 Mbit/s	100 Mbit/s
Transfer Mode	Full-Duplex	Half-Duplex	Full-Duplex	Half-Duplex	Half-Duplex	Half-Duplex
Max. Jitter	<1µs	20µs	1µs	1µs	1µs	1µs
Fault Tolerance	Yes	No	No	Yes	No	No
Timing Model	Synchronous Cyclic	None	Cyclic	Cyclic	Mixed Polling / Time Slicing	Isochronous Channel
Real-Time OS Required†	No	Yes	Yes	No	Yes	No
Fast I/O Capture & Time/Position Interpolation	Yes	No	No	No	No	No
Network Programming Required	No	Varies	No	Yes	No	No
Current Status	Shipping Globally Since 2002	Available	Available	Products still under development. Very few field applications. Some specified features not validated.	Available since 2003	Available
Next Generation	500Mbit/s + 500Mbit/s (Full-Duplex)	500Mbit/s + 500Mbit/s (Full-Duplex)	-	-	-	-
Next Generation	(100+100)Mbit/s	(100+100)Mbit/s	-	100Mbit/s	100Mbit/s Version II	-

**SynqNet achieves fast cycle updates by several methods.**

- .: During network auto-setup – Discovery Mode – node distance is calculated by the controller to all nodes to reduce natural skew introduced over CAT5 cable.
- .: The Phase-locked loop technique is employed to generate stable frequencies and a constant ‘heartbeat’ to set master timing for guaranteed data delivery and synchronized communication to all nodes.
- .: Flexible FPGA programming lets users modify background versus foreground task management to mitigate application requirements.
- .: Lightweight packet structure.
- .: Optimized programming software with close coupling to controller and hardware design.
- .: Robust software utilities to optimize timing and tuning of all nodes on a SynqNet network.



Data delivery is ensured via synchronized node clocks (PLL) to a master clock to keep jitter and skew thresholds to nanosecond accuracy. This architecture allows for fast position capture techniques and custom timing values.

**High Speed I/O Position Capture**

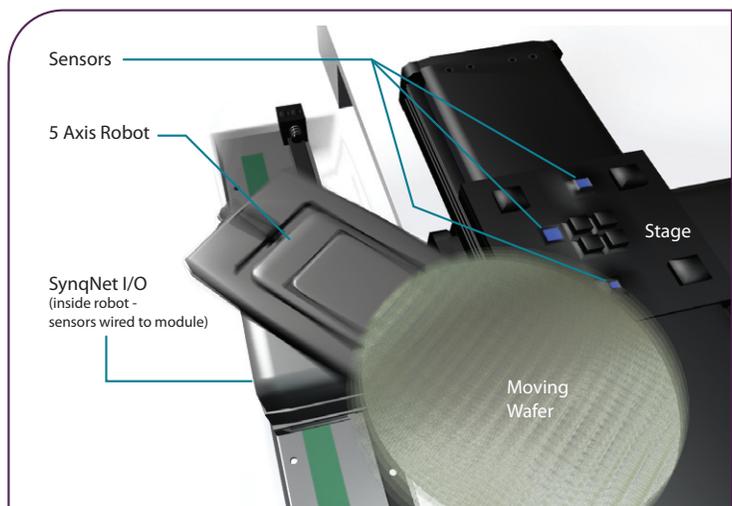
Time-based capture works by analyzing the position at the servo cycle before and after the time when the FPGA register is triggered by a digital input. Extremely accurate position data based on time (~100ns) can then be interpolated. The controller in a SynqNet network does the position interpolation calculations, so the motion application only needs to read the interpolated capture position. In addition, all data from every node is gathered each servo cycle and is processed by a central controller. A trigger on any node can be used to determine position on any other node in an entire SynqNet network. The advantage then is the ability to place a sensor next to any node in a SynqNet network and use the sensor to capture position on any other node in the system. Dedicated I/O can be wired through the closest node available on the network. The wiring elegance this affords in machine architecture reduces costs and minimizes implementation time. This type of position interpolation based on time stamps across SynqNet is an industry first.

**Probe**

Probe is a more specialized position or time-based capture technique. Probe can be utilized to allow for multiple dedicated registers to capture a series of I/O triggered values, even if the multiple triggers occur in a single servo sample. Up to 16 values can be automatically armed and set to record data repeatedly. The recorder object in software is utilized to record these data sets and buffer the data for the host, then the application can collect the data, process it, and command or modify moves. The trigger mechanism is automatically re-armed every servo sample by the FPGA. Probe is a powerful feature when multiple I/O points need to be captured and re-armed quickly to record data sets at very high rates. This can be

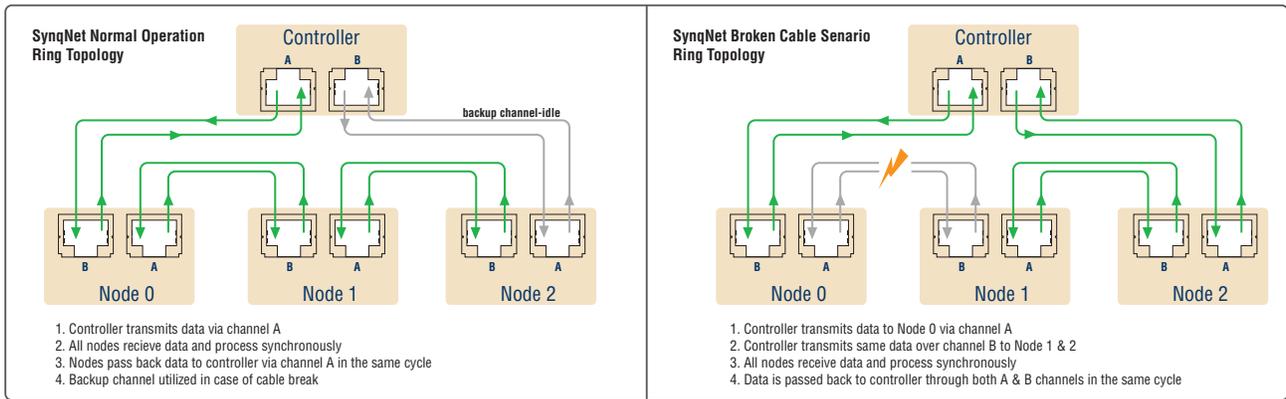
particularly useful for calculating multiple locations of product in a machine very quickly that subsequently need to be moved to another part of the machine. Also, trajectory-on-the-fly calculations can be made if the I/O is situated to gather time or position values as an object moves quickly over a series of sensors as in the example below.

- .: A robotic arm is moved over a bank of sensors wired to SynqNet I/O.
- .: The sensors are triggered as the wafer passes over. SynqNet I/O can handle up to 16 simultaneous high-speed capture inputs (~100ns).
- .: The interpolated position is calculated to determine the precise wafer position and this data is used on the next servo sample to modify the robotic axes, ensuring high repeatability and fine resolution accuracy.



## Safety and Reliability

### “Self-Healing”, Fault Tolerant Operation Increases Safety and Availability



SynqNet can be configured in either a string or a ring topology. The string or ring topology offers convenient wiring and tolerance to cable breaks within a SynqNet system.

“Self-Healing” fault tolerance refers to an ability to operate after an actual cable break, loose connection, or complete fault of any node or nodes. As an example, if a node fails, SynqNet is able to control the remaining nodes on the network, flag the application, and then execute alternative motion parameters. A closed ring ensures that there is always a redundant data path for transmitted data through the entire ring. SynqNet uses this redundant path as a secondary data channel.

In the event that a wiring segment fails, SynqNet hardware re-routes the data path within two servo cycles and the network connection remains available. At the same time, the application will be informed about the event and event location, allowing the machine to respond in a manner appropriate to the specific situation. For example, a machine

can be programmed to finish a move sequence that would otherwise cause a dangerous or expensive collision of independent or interlocked machine axes.

In addition, each node has its own watchdog timer so even if the host or whole network fails, each node can react in a predictable and safe way for a smooth and controlled shutdown. To predict possible network failures, SynqNet includes transmission error counters at every node. Any abnormal increase in error counts can be used to alert the application software and localize the potential problem before it becomes a catastrophic failure. SynqNet utilizes 100BaseT CRC error checking.

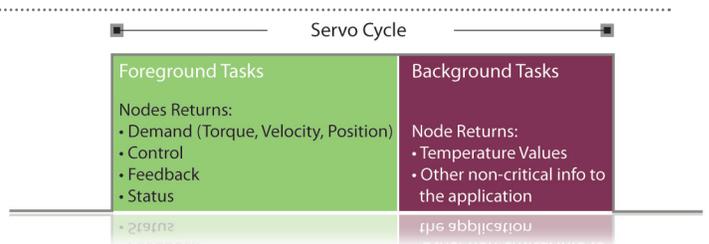
SynqNet is the only commercially available network that offers this level of safety and reliability. Fault tolerance is important in all digital network systems, especially high value applications and medical applications where redundancy is crucial for cost savings and/or safety.

### Drive Monitor Functions

The Drive Monitor is a real-time monitor mechanism that allows the monitoring of up to three internal drive variables every servo sample. This ensures that constant data about all the drives in a network can be monitored and that an appropriate action be executed should a parameter exceed a threshold for tolerance such as temperature. The data can be recorded against known operating parameters to present a useful analysis tool for optimizing machine performance or checking for degradation of performance on any given axis.

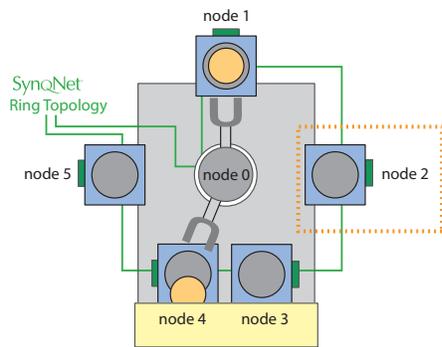
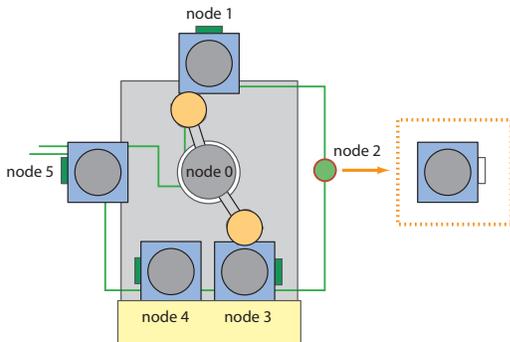
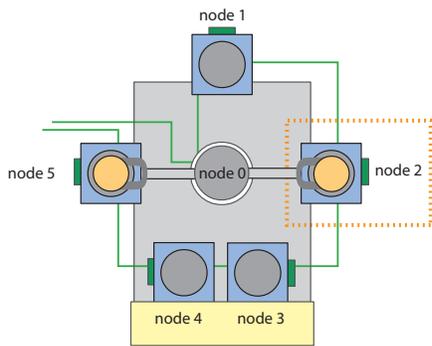
The robust service channel built into SynqNet allows this data to be read as a background task every servo sample and recorded by a host computer. SynqNet is enabled to monitor key performance and diagnostic data every servo sample without interfering or degrading application performance.

SynqNet does not require mode change or shutdown / restart to utilize the service channel capabilities.



Drive monitor can capture data each servo cycle for **all** axes. Other networks offer some form of drive diagnostics but often for only one node at a time.

- |                           |                  |
|---------------------------|------------------|
| :: Temperature            | :: Actual torque |
| :: U, V & W phase current | :: Analog inputs |
| :: Drive memory           | :: Bus voltage   |

**HotReplace™****1.****2.****3.**

The SynqNet HotReplace feature allows one or more consecutive nodes to be shut down, serviced, and then reattached to the system without affecting the operation of the other nodes.

**1. Normal Operation**

∴ SynqNet connects all nodes, and I/O in the system.

**2. Take Module (Node 2) off-line for Service**

∴ Axes & I/O associated with node 2 are taken off-line. All other nodes in the machine remain operational.

**3. HotRestart**

∴ When the HotRestart function is called, the host searches the SynqNet network for any and all nodes that have been replaced or if an exact duplicate has been added in its place, and restores them to normal cyclic communication. At this point the application performs homing and other initialization, and then resumes normal operation.

**No Machine Shutdown - Service on your Schedule**

The SynqNet HotReplace feature is especially useful for systems where modules are occasionally taken offline for regular maintenance or replacement. Many high performance systems would require the whole system to be shut down in order to service a module. When using the HotReplace feature, modules can be safely taken offline for servicing and then be replaced while the rest of the system remains fully operational. The implications for cost savings and ultra-low downtime is substantial given modern manufacturing processes where throughput and quality are critical to success.

## Future SynqNet Development Interest Group Growth and R&D Investment

The SynqNet Interest Group and SynqNet Development Team are working hard to expand the number of SynqNet interoperable devices, manufacturer selection and core functionality. SynqNet Masters will emerge with new software interfaces including Visual Basic programming, IEC 61131, and script. New devices from existing and new SynqNet partners are in the development pipeline. SynqNet core functionality is growing with increased axis counts, increased I/O nodes, and overall raw data capacity.

As demands for productivity and price competitiveness increase for automation engineers, SynqNet will continue to offer fast, safe, proven technology and solutions. Engineers can create differentiate systems with SynqNet Reference Design Kits for in-house designs. Engineers can use SynqNet real-time data from controls, drives and I/O to create a fully transparent digital machine with expanding intelligence.

Automation engineers want flexibility and interoperability in a network that does not compromise performance. Fast, safe and proven; SynqNet delivers.

## **SynqNet Interest Group Contact Information**

The SynqNet Interest Group is open to anyone interested in learning more about SynqNet and why it is the most widely accepted motion network.

Membership is free. Join today and receive exclusive access to SynqNet case studies, white papers, eNewsletters, SynqNet Experts, and invitations to SynqNet conferences.

Learn more at <http://www.synqnet.org/interestgroup/>

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